



RESEARCH DEPARTMENT

VISIT TO U.S.A. AND CANADA — JUNE 1956

Report No. A-042

(1956/27)

**THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION**

RESEARCH DEPARTMENT

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T. Somerville, B.Sc., M.I.E.E., F.Inst.P.

A handwritten signature in cursive script, appearing to read 'T. Somerville'.

(T. Somerville)

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SUMMARY

The Second International Congress on Acoustics was attended at Cambridge, Massachusetts, and following this visits were paid to broadcasting organisations and laboratories engaged on acoustic research in U.S.A. A visit was also paid to the Canadian Broadcasting Corporation.

1. INTRODUCTION.

The primary purpose of the visit to U.S.A. was to attend the Second International Congress on Acoustics at Cambridge, Massachusetts. The International Union of Pure and Applied Physics decided after the war that the subject of acoustics had been neglected and to remedy this it appointed the International Commission on Acoustics. The International Commission on Acoustics arranged its first congress at Delft in 1953 and at that time decided to hold international congresses at three-yearly intervals. At the congress which has just taken place it was announced that the third will be at Stuttgart in 1959.

After the congress the opportunity was taken to pay brief visits to the principal organisations in U.S.A. and Canada engaged in the field of acoustics. Visits were paid to the National Broadcasting Company and the Columbia Broadcasting System in New York; the Bell Laboratories at Murray Hill, New Jersey; the R.C.A. Laboratories at Princeton, New Jersey, and the National Bureau of Standards in Washington.

In Canada the studio premises of the Canadian Broadcasting Corporation were visited in Toronto, Ottawa and Montreal. On the way from Washington to Toronto the journey was broken at Buffalo to study the Kleinhans Music Hall.

2. INTERNATIONAL CONGRESS ON ACOUSTICS.

This took place in Cambridge, Massachusetts, from Monday, 18th June to Saturday, 23rd June inclusive. The meetings on the first two days were held in the Massachusetts Institute of Technology premises, the second two days at Harvard University and the final two days again at Massachusetts Institute of Technology. In addition to the actual technical sessions, visits and one or two social events were arranged for the delegates. This is a much more difficult congress on which to report than the first one at Delft because of the large number of papers. The normal procedure was to allow 12 minutes for a paper with 3 minutes discussion, but as many authors over-ran their time the discussion frequently was sacrificed. Another serious disadvantage was the use of slides in auditoria where it was not possible to dim the lighting, for this meant that many of the sessions were in more or less

complete darkness and it was impossible to take notes. The large number of contributions was due to the fact that this congress was held in conjunction with the annual meeting of the Acoustical Society of America with a consequent large attendance of 900 delegates. In all there were 284 papers, under 9 classifications, as follows:

- Architectural Acoustics
- Bioacoustics
- Musical Acoustics
- Speech Analysis and Synthesis
- Physical Acoustics and Sonics
- Geophysical Acoustics
- Loudspeakers and Sound Reproduction
- Noise Control and Measurements
- Radiation and Scattering of Sound

After the opening ceremonies on the morning of Monday, 18th June, a general symposium on the subject of bioacoustics and noise control was held for all the delegates. Papers were read on the behaviour of human beings under conditions of noise, the calculation of loudness of noise and the effects on speech under very noisy conditions. While of general interest, these are academic subjects to a broadcasting organisation, where noise is normally kept to a minimum. In addition there was an interesting survey of the techniques of noise control, mainly with reference to noise in factories and offices.

On the evening of 18th June there was a demonstration of speech analysis and synthesis given by Lawrence of S.R.D.E., which was exactly similar to the demonstration he has already given in this country to the I.E.E. and to the Acoustics Group of the Physical Society. Following this another demonstration of speech synthesis was given by G. Fant of Stockholm which, although it did not reach the standard of the S.R.D.E. demonstration, appeared to be more flexible and consequently capable of greater development. A very humorous finale to these demonstrations took the form of a duet sung by both pieces of equipment.

On Tuesday, for the benefit of all the delegates, a survey paper was read by Georg von Békésy on the mechanics of the cochlea. Békésy is a refugee Hungarian who has now worked at Harvard University for many years and is well known for his investigations into the theory of hearing. This paper was of very great interest.

A brief survey only will be given of the more interesting papers.

2.1. Noise Control and Measurements.

2.1.1. Noise Reduction by Partial Enclosures, by Franklin G. Tyzzer, D.E. Bishop and H.C. Hardy.

The use of partial enclosures to reduce noise has not been extensive in the B.B.C., although the method has been employed in several control rooms to screen monitoring positions. No investigation of this problem has been made however. The data given in this paper may therefore be of value. It was found that for enclosures without a top and 2, 3 and 4 sides, reductions in interfering noise of between 6 and 10 dB could be obtained. At distant points where ceiling reflections caused trouble,

ceiling treatment at suitable positions could give up to 12 dB improvement. The addition of a top to the enclosure increased the improvement up to 25 dB.

In connection with experiments on acoustic models a new device for making wide-band noise was described. It consisted of a steel cylinder containing a rotating paddle to throw steel balls against the cylinder walls, so producing a noise with a spectrum between 2 and 50 kc/s.

2.1.2. Reducing Noise in a Sugar Refinery, by Auguste C. Raes.

The particular trouble in this sugar refinery was very high-frequency noise in the region of 4000 c/s. It was caused by high flow velocity in pipes, the hiss produced by valves being radiated from the whole system of piping. It was not possible to apply any treatment to the pipes. The final solution, which proved to be effective, was to place functional absorbers on both sides and underneath the pipes at a distance of 1 ft. These functional absorbers consisted of 1 in. thick plates of absorbent material. This gave a reduction of 10 dB in the region of 4 kc/s and although it did not remove the noise entirely the reduction proved to be satisfactory.

2.1.3. Measurement of Noise from Cooling Towers, by Laymon Miller and Ira Dyer.

Although on the face of it this would not appear to be of immediate interest to the B.B.C. it is, in fact, a useful description of the method of measuring noise from the cooling towers used for air conditioning in the United States. The hissing sound from such towers, which are usually placed on the roofs of buildings, can be very disturbing and in residential districts steps have to be taken to reduce the noise. The paper contains data on the approximate proportion of noise contributed by the various sources of noise in a typical cooling tower.

2.1.4. Noise from Centrifugal Fans, by Clayton H. Allen.

It is not possible to report very reliably on this very technical paper although it appeared that the data on noise may be of great help in the design of fan systems. Empirical relations have been obtained which indicate that an optimum relation exists between air speed and pressure head which will minimise noise for a given horsepower delivered from a fan of a given size.

2.2. Symposium on Architectural and Musical Acoustics.

2.2.1. A Musician and His Acoustical Environment, by E. Power Biggs.

The author, who is an organist, disagrees with the present methods of voicing organs and believes that the classical method is much superior. The difference lies in the fact that the modern organ is voiced by nicking the lip of the pipes whereas the old method was to bend the lip. He demonstrated with recordings that the classical method gives a starting transient which gives character to the note. On the question of environment he is against the enclosing of organs in chests because he believes that this confuses the sound and, in addition, because of the temperature rise, changes the tuning. He advocates reverberation times in excess of 2 sec and furthermore asserts that with very long reverberation times there is no danger of

losing definition. He appears to think that the only characteristic which matters is reverberation time, which should be long, and did not discuss the importance of diffusion of the sound energy, although this is obviously another notable characteristic of old churches. He is opposed to the use of reflectors, expressing the opinion that a reflector is necessary only to enable speech to be heard when the reverberation time is long. This is not the experience of most workers in the field. For example in St. Paul's Cathedral where the reverberation time is very long the only solution is a sound reinforcement system to enable the sermons to be heard throughout the church.

2.2.2. Optimal Acoustical Design of Rooms for Performing, Listening and Recording, by W. Kuhl.

This paper was a repetition of work already published by this author in *Acustica*¹. His conclusions are quite controversial and quite contrary to experience in the Corporation. He claims, for example, that subjective experiments show the preferred reverberation time for music by Mozart to be 1.5 sec, for Brahms 2 sec and for Stravinsky 1.5 sec. If this were true it would make the life of the acoustical designer extremely difficult, for the same orchestra has to play all kinds of music in the same studio and to obtain changes in the reverberation time of this order would be impractical. In the B.B.C. such a difficulty does not arise. In Maida Vale 1, for example, all kinds of music, both romantic and modern, can be played with a reverberation time which is in the region of 1.8 sec. It is also known that in good concert halls with reverberation times approximating to 2 sec it is possible to perform modern music without difficulty as regards hearing conditions or microphone placing. There is no means of knowing where Kuhl may have gone wrong, but from our own experience of subjective experiments it would seem probable that he has not controlled his experiments with sufficient care.

In discussing talks studios Kuhl recommended reverberation times of between 0.35 and 0.45 sec (a little longer than is acceptable in the B.B.C.) and stated that excessive reverberation time at low frequencies can be corrected by a high pass filter. This ignores the fact that such a method only reduces the studio output at low frequencies without removing the colourations which are often in the pass band of the filter.

Once again he has reiterated the German belief that rectangular diffusers are not as good as circular or cylindrical types, a statement based entirely on laboratory experiments with plane waves and under conditions where the wave-length is small compared with the dimensions of the diffusers. The practical condition is normally very different, for it is at low and medium frequencies that diffusion is difficult to obtain and in this region the diffusers are very often comparable with the wave-length. Under these conditions there is no doubt that rectangles are better than other shapes, a fact which has been confirmed independently by both Brüel and Lamoral.

A further point on which we disagree is the use of diffusers in talks studios only to scatter first reflections and not for general diffusion. It also appears that Kuhl does not favour the random distribution of absorption in small studios. It is difficult to understand how he can support these claims because unless absorption is distributed it is inefficient except for particular normal modes.

At the end of his paper, in discussing concert studios, he advocates a canopy over the orchestra to reinforce sound and favours strong reflections from immediately behind the orchestra. This, of course, is the standard theory on which so many modern concert halls, including the Royal Festival Hall, have been constructed. The results in the writer's opinion leave much to be desired.

2.2.3. Physical Measurements in Rooms and Their Meaning in Terms of Hearing Conditions, by Erwin Meyer.

The title of this paper was rather misleading. Although the author discussed various physical measurements in rooms, he said little about the relation of the measurements in terms of hearing conditions. The actual measurement methods described and the theories propounded have been current in Germany for some time. He explained that the double slopes of reverberation curves were caused by the different rates of decay of various modes in a room but did not explain how this was to be related in terms of the hearing conditions, nor did he say anything about the known fact that such double slopes can be overcome if the diffusion is made adequate. He appeared to make the surprising statement that for music purposes the reverberation time at 2 kc/s should be as long as possible. It is our experience that a slight increase is desirable at this frequency in certain conditions, with light orchestras which often have too few strings, for the increase in reverberation time helps to reinforce stringed instruments, but that the increase in reverberation time should not be overdone.

He reported that the Germans have been carrying out experiments to determine preferred reverberation times by making recordings under "dead" conditions and increasing the reverberation time by using reverberation chambers. We have found that this procedure is suspect because in small reverberation rooms the reverberation consists of a large number of reflections having short path lengths which, when added to the original music, give the inartistic effect of a large orchestra in a very small room.

2.3. Noise Control in Buildings.

2.3.1. Review of the Netherlands Study of Noise Control in Multiple Dwellings, by J. van den Bijl, M.L. Kasteleijn and C.W. Kosten.

Some time ago the Netherlands, France, Denmark and Great Britain reached agreement on the measurement of sound insulation. The authors reported the experiments to correlate objective measurements with subjective assessments in flats in Rotterdam and The Hague. They also described, very mathematically, a method of estimating the "flanking" transmission in structures. The opinion was expressed that the sound insulation of partitions should be plotted as a function of frequency and not as a mean value, which can be confusing. The desirability of being able to place the insulation of panels and walls in rank order by a single number was also emphasised.

2.3.2. Standards of Sound Insulation in Buildings, by Alan T. Pickles.

This describes the need for the continual survey of standards because of the changes in methods and materials of building and the arrival of new sources of noise,

such as aircraft. An opinion survey has recently been carried out from which it is hoped to assess the reaction of occupants of rooms separated by floors having various measured degrees of insulation. It is hoped that some agreement between subjective and objective measurements will be obtained.

2.3.3. Some Contributions to Standards on Measurements in Architectural Acoustics, by Richard V. Waterhouse.

Work is at present in progress at the Bureau of Standards to devise methods, for the measurement of sound absorption of materials in a reverberation chamber, which are not affected by the position of the sample in the room. The Bureau of Standards recommends the use of one sample. This differs from the method favoured in Europe, with the exception of the N.P.L., which is to distribute the samples on three surfaces mutually at right-angles. It is known that the European method sometimes gives absorption coefficients greater than unity because of diffraction round the edges of smaller samples, although it is agreed that the distribution of the samples represents practical conditions. Much work will have to be done on this particular subject before international agreement can be obtained.

2.3.4. Subjective Method for the Evaluation of Sound Insulation, by J.J. Geluk.

The author described electronic circuit analogies by which he claims it is possible to predict the behaviour of all types of construction to air-borne sound. A recording of the sound level on the site of the future building can be made and passed through the analogous networks so that the change obtained by the proposed constructions can be heard. If the author's claims are correct, this may be a valuable tool in designing and predicting the behaviour of constructions for sound insulation.

2.4. Auditorium Acoustics and Measurements.

2.4.1. Distribution of Sound Intensities and Path Time Difference of Reflections in Halls, by George R. Schodder.

Measurements have been made of the number of sound reflections arriving at different positions in broadcasting studios, concert halls, theatres and a church. The results were analysed to show the path time differences of the reflections and the number of reflections which were not more than 10 dB below the level of the primary sound. In some cases the number of reflections falling at different seats in the same hall were considered. In addition, the general influence of the position of the sound source on the reflections was indicated. An endeavour is now being made to correlate the results with the subjective effects of reflections. The paper was extremely interesting because one of the halls mentioned was the Royal Festival Hall. The efficiency of the reflectors in this hall in concentrating energy was demonstrated and another important point was that the number of reflections not more than 10 dB below the primary sound is about half that obtained in any of the other halls. Only in dead studios is the number of reflections less. This is a further interesting confirmation of the peculiar acoustics of the Royal Festival Hall.

2.4.2. Determining Acoustic Quality from Reverberation Curves, by P.V. Brüel.

Brüel is well known for his work in acoustics. He has always been extremely interested in the pulse glide technique and sells equipment for making acoustical analyses by this method. He realises the difficulties in interpretation and this paper contains suggestions for overcoming them. He suggests that if warble tone is used instead of pure tone a series of curves similar to a pulsed glide will be obtained. These decay curves often have a double slope similar to that shown in Fig. 1 and he suggests that the slope of the latter part of the decay curves compared with the initial slope may provide a quality factor for the room, given by the following relation

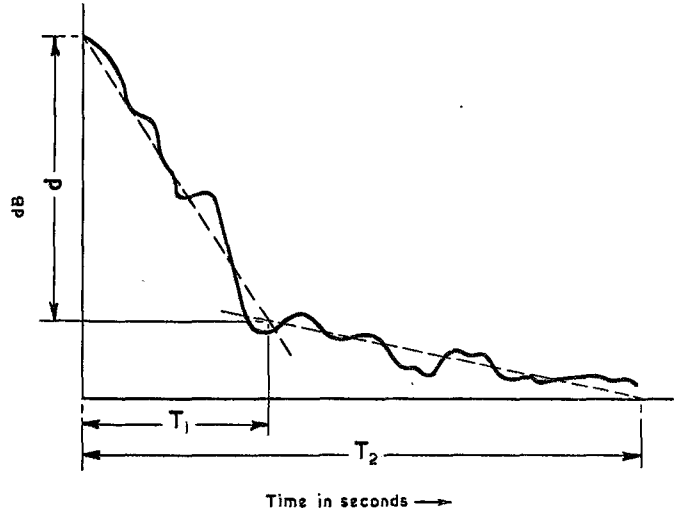


Fig. 1 - Brüel criterion

$$\text{Acoustic Quality} = \frac{T_1}{(T_2 - T_1)d}$$

where T_1 , T_2 and d are as shown in Fig. 1.

It should be noted that Ward of Research Department has suggested that the differences in slope in a reverberation curve might be used to measure the diffusion in a room. Such changes of slope, when due to an undamped normal mode, can often be removed by increasing diffusion. If due to a structural resonance they are not affected by diffusion. An investigation of this aspect of diffusion has been proceeding in the Department for some time.

2.4.3. Empirical Acoustic Criterion, by T. Somerville and J.W. Head.

Further objective and subjective investigations have been carried out to test the validity of a tentative acoustic criterion which has already been described in *Acustica*². This paper discusses the investigations by means of which it has been possible to establish for large enclosures an improved version of the original criterion, and also the new criterion which takes account of volume. A nomogram for the new criterion was described. For small enclosures, such as talks studios, it has been impossible so far to obtain satisfactory criteria, and further investigation is in progress. Part of this investigation is the investigation of double slope reverberation characteristics, mentioned in the comments on the previous paper.

2.4.4. Diffusion Properties of Various Irregular Panels, by Chester M. McKinney and Richard N. Lane.

Measurements of scattering by various types of 8 ft square wall panels were described in this paper. Measurements were made with flat, corrugated and triangular

splayed panels and also for panels with rectangular and polycylindrical irregularities. The results showed that the rectangular irregularities were the most effective, a further confirmation of Research Department's experiments.

2.4.5. Scale Model Investigations for Large Auditoria, by Roger Lamoral.

This author described the method used by Radiodiffusion-Télévision Française in employing scale models and ultrasonic frequencies to investigate the reflections from the boundaries of large auditoria. The apparatus is being used to check the designs for the Radiodiffusion-Télévision Française building in Paris. Lamoral has also confirmed our results on the relative merits of rectangular and cylindrical diffusers.

2.4.6. Design, Construction and Testing of the M.I.T. Kresge Auditorium, by R.B. Newman.

It was in this auditorium that the principal meetings of the Congress were held. It is a modern building and is shown in Fig. 2. Although it was well known

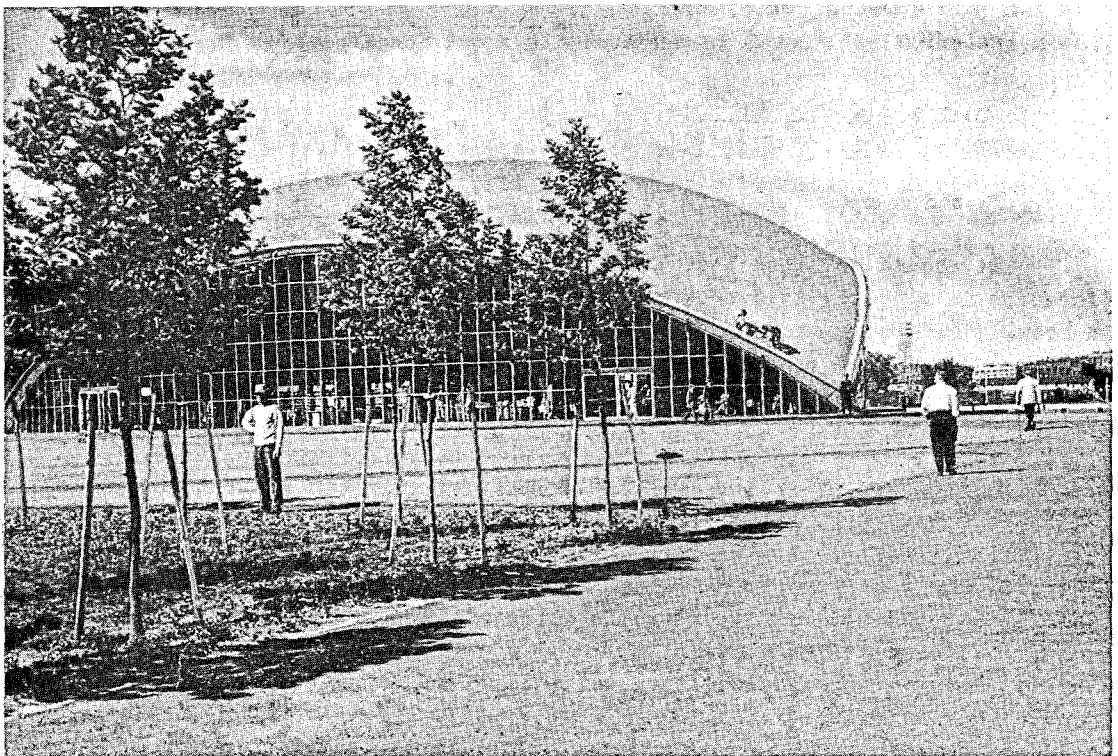


Fig. 2 - Kresge Auditorium

at M.I.T. that such a shape would present difficult acoustical problems, it was decided to proceed with the project to check the methods necessary to construct the unique form which had been adopted. The roof is a section of a sphere supported at three points at ground level. The untreated shell had, as expected, very bad acoustics but this was corrected to some extent by adding a false ceiling above which

such services as ventilation are concealed. Splays were also fitted round the stage and by these means reasonable acoustics have been obtained. Nevertheless, the auditorium cannot be said to be entirely satisfactory. A reinforcement system is necessary although the auditorium is not large. An organ has been installed but, as the reverberation time must be kept down because of the shape, the organ tone lacks fullness.

2.5. Musical Acoustics.

2.5.1. Principal Considerations on the Artistic Qualities of Musical Sound, by Erich Thienhaus.

This was a most interesting paper because the author has endeavoured to explain some of the finer points of musical quality by suggesting that phase changes at reflecting surfaces are important and that if the best quality is to be obtained these phase changes should be random. He also considers that there should not be wide variations between the coefficients of absorbing surfaces; in other words the absorption should be well distributed.

2.5.2. Some Problems of Reproduction and Perception of Electronic Tape Music, by Werner Meyer-Eppler.

The Germans have now established an electronic music studio in Cologne using apparatus similar to that described by the author. He has constructed apparatus to produce, in addition to the correct pitch, various transients and envelope formations, formant frequencies, noise colours and reverberation characteristics. He gave demonstrations by means of recordings which appeared to the writer to indicate that his methods led to results which were rather unusual. There was an abundance of wow and distortion in addition to other queer sounds which were apparently intentional.

2.5.3. High-Fidelity Philosophy from a European Standpoint, by J. Rodrigues de Miranda.

The beginning of this paper amounted to a dull piece of theorising but the interesting point came out that some Philips loudspeakers are now provided with a high impedance voice coil of 800 ohms to eliminate the output transformer in conjunction with a push-pull single ended stage. The author, when questioned on the difficulty of winding voice coils of this impedance, stated that a technique using very fine wire had been evolved.

2.5.4. A Distributed Loudspeaker, by Sipko L. Boersma.

This paper described a novel type of "distributed" loudspeaker consisting of a double exponential horn in the side of which is placed a steel plate two mils thick energised as a diaphragm by a moving coil unit, as shown in Fig. 3. The author claims that the structure presents to the

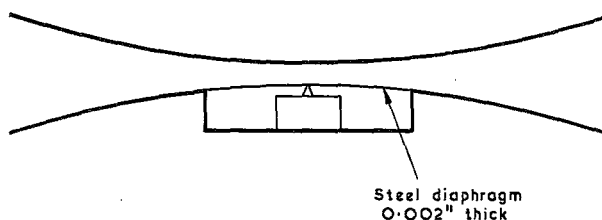


Fig. 3 - Distributed loudspeaker

driving mechanism a mechanical impedance which can be calculated and which is real and constant over a wide frequency range. No demonstration was given, but the device might bear investigation.

2.5.5. An Apparatus for Alteration of the Playback Time of a Sound Record,
by Anton M. Springer.

It will be remembered that during the war the Germans produced a recorder known as Tonschreiber B which, by means of a rotating head system, could change the duration of a recording without altering the pitch. It was designed to aid in deciphering high speed morse messages. Several versions have subsequently been developed and it is claimed that the latest device is now suitable for use on high quality programme material. Time expansions up to 200% and compressions of 50% are stated to be possible but it is doubtful whether these large differences are acceptable in view of the distortions which may be introduced. The demonstration given was badly organised and quite inconclusive. An earlier version of the machine was investigated by Designs Department³ and found to be unsatisfactory.

2.5.6. Learning, a Major Factor Influencing Preferences for High-Fidelity
Reproducing Systems, by Roger E. Kirk.

It has always been suspected that listeners become conditioned to their own standards. This paper is an interesting attempt to evaluate the effect of experience on the opinions of subjects listening to high quality electro-acoustic reproducing systems. Two groups were used; one listening to music reproduced between 30 and 15 000 c/s, while the other group listened to 180-3 000 c/s. After they had listened for two hours a week for thirteen weeks, tests were carried out which purported to show that the subjects preferred the particular bandwidth to which they had been listening. From the brief description given the experiment did not seem very convincing.

2.5.7. Displacement Pickup for Measuring the Motion of a Loudspeaker Cone
at Many Points, by K.R. McLachlan.

The author, who is a lecturer at Southampton University, has devised a photo-electric method of observing the movement of loudspeaker cones. About 30 points on a radius are sampled by a scanning system driven by an electric motor. This system may be worth investigation in connection with development work on loudspeakers.

3. MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Much of the work at present in progress in the acoustics laboratory is of little interest in broadcasting. For example, investigations are in progress on absorption in gases at high temperatures, on acoustic measurements in the human vocal tract, on the construction and calibration of hot wire probe microphones and on many aspects of biological ultrasonics. Much of the programme is concerned with the analysis of speech and with bandwidth compression.

The impedance of acoustical materials can be measured with great precision and a small sound measurement room is available. There is also a studio which can be

used for experiments in acoustic treatments but this is mainly employed at present as a sound source for experiments in other parts of the building.

3.1. Speech Analysis and Synthesis.

Automatic machines are being developed for the recognition of certain attributes of speech. An electronic device for separating vowels and consonants occurring in continuous speech was demonstrated.

A speech synthesiser is also being developed using a transmission line with electronically variable elements to simulate the human vocal cavities. All vowels can be synthesised and another circuit simulating nasal characteristics can be added for nasal consonants.

Work on speech bandwidth compression is also proceeding. Development of a system in which it is hoped to use a bandwidth of 50 c/s is going on.

A delayed speech feedback loop was being demonstrated. This is a favourite demonstration for "at homes" in this country and was first shown by Engineering Training Department. The subject talks into a microphone and listens to himself with earphones. As he talks, the signal to the earphones, which is being reproduced from a tape recording, is delayed by moving the reproducing head. When this delay reaches about 200 ms most subjects find it very difficult to go on talking.

3.2. Outdoor Sound Propagation.

An elaborate series of experiments is in progress at a field station near Boston to determine experimentally how sound propagation is affected by such factors as terrain, wind and temperature gradients, etc. The sound source is a jet noise which is measured at various heights and distances up to 1 mile from the source and in the analysis an attempt is being made to correlate changes in the measured sound field with changes in ground cover and weather conditions.

The laboratories are disappointing by modern standards. Although the quality of work carried out is high, the accommodation is rambling and badly laid out; this is no doubt due to the fact that it has been modified from its use for other purposes.

4. ACOUSTICS RESEARCH LABORATORY, HARVARD UNIVERSITY.

One of the largest sound measurement rooms ever built is situated at Harvard University. Its interior dimensions are 29 ft x 41 ft x 29 ft. This room is used for free field experiments in connection with the work of the laboratory. An interesting method of producing random noise was being demonstrated. The generator consists of a frame approximately 20 ft in radius, the centre of the circle being positioned at the centre of the working space in the room. Around this frame at 5° intervals are placed small loudspeakers carefully selected for uniformity in performance and each acoustically damped with fibreglass to eliminate resonances. Each is fed from a separate noise generator. It was shown that if all were fed from the same noise generator it was possible to locate the centre of the circle acoustically by moving

about in the room but that localisation became impossible when each loudspeaker was fed from a separate source. The loudspeakers have a uniform characteristic between 500 and 3000 c/s, in which region conditions are found to be truly random.

Work has been going on intermittently for some years on the development of electrostatic loudspeakers to be used as sound sources for laboratory investigations. Various types, including spherical loudspeakers, have been developed but none so far is suitable for broadcasting.

Other work in progress in these laboratories is the physical measurement of acoustic materials. The laboratory can measure flow resistance and acoustical impedance and is also equipped for the calibration of condenser microphones by the reciprocity method.

A diffuse sound chamber has been constructed using polycylindrical diffusers on all walls and the ceiling to provide excessive diffusion for experimental purposes. During the visit, however, no work was going on in this room.

An interesting historical relic is the original reverberation chamber in which W.C. Sabine carried out all his early investigations.

The layout of the accommodation at Harvard University is typical of good university practice. It has not the luxury of the modern commercial research laboratory neither is it old fashioned.

5. NATIONAL BROADCASTING COMPANY, NEW YORK.

There was time for only a very brief visit to N.B.C. in New York. No modern N.B.C. studios for either sound or television are in New York and it was therefore not possible to study the latest techniques.

There is much published data on the optimum reverberation time for sound studios but so far little information has been published regarding television studios. This matter was discussed but no definite information was available, apparently because the matter has not been considered very much and there is as yet no consensus of opinion.

It was noted in N.B.C. that the sound mixer is isolated from the rest of the team — a practice which is favoured in the B.B.C.

One of the difficult problems in B.B.C. television is to find ways of producing proper acoustic perspective. In many of our drama programmes there is no difference in acoustic perspective between indoor and outdoor scenes and between indoor scenes with very different acoustic settings. It appears that in N.B.C. in New York no attempt is made to solve this problem. In Los Angeles, however, where the weather is consistently good, outdoor scenes are normally taken outside.

It was discovered that a new second order pressure gradient microphone has been developed by R.C.A. and is apparently much favoured by the programme staff in television studios. Details of this microphone were obtained during the visit to R.C.A. Laboratories at Princeton.

In news and talks items it is customary for each speaker to have a personal microphone. These took many forms; some of them are relatively unobtrusive while others are very obvious indeed, various types being seen in any one programme. In general the sound quality in N.B.C. leaves much to be desired.

6. UNITED NATIONS BUILDING.

The United Nations building was visited to look at the various halls because of their interest acoustically. The main assembly hall is a good example of an architect being unreasonable regarding acoustics because of insistence on the use of a dome. The result is that, although acoustic treatment has been carried out with ingenuity, it is impossible to eliminate all bad effects. A sound reinforcement system is therefore necessary. It consists of a horn loudspeaker in front of the chairman's desk and some loudspeakers operating at low level for seats in recesses at the sides of the hall. All delegates must speak from the platform.

In the other halls in the building headphones are provided at every seat for the translation service and all speakers have microphones.

7. BELL LABORATORIES, MURRAY HILL, NEW JERSEY.

At Bell Laboratories the main effort is obviously directed towards the interests of the telephone and other U.S. communication services. In connection with investigations on speech and hearing a non-reverberant room has been provided. It was the first room to have a tensioned wire floor and the first one I saw in U.S.A. having all the wedges enclosed in chicken wire to give them rigidity. So far this method of enclosing wedges has not been employed in Europe and on the face of it would be expected to cause reflections at very high frequencies, but the method seems to be general now in the United States where it is said that the high frequency absorption is not affected. This is an important point which we must investigate because, although enclosing the wedges in this way will increase the initial cost, the system is much more durable and the treatment should therefore last indefinitely.

An interesting development demonstrated was an electrostatic microphone which consists of a large sheet of aluminium foil, the dimensions being about 4 ft x 2 ft, insulated from a rigid metallic backing by a thin layer of sorbo rubber about $\frac{1}{32}$ in. thick. The polarising voltage is about 700 volts. Because of its large area this microphone has directional properties and is used in the Lecture Theatre at Murray Hill, being placed horizontally over the head of the lecturer who can move about underneath and turn in any direction without affecting the pickup for the public address system. Such a microphone might have uses in such television items as the weather forecast, provided it did not interfere with lighting.

No other microphone developments are taking place in the organisation, all the microphone production of the Western Electric Company having been handed over to Altec Lansing because of some complication caused by the anti-trust laws. The major activities of this laboratory go into the analysis and synthesis of speech which is of paramount importance to the Bell System in its endeavour to save bandwidth on long trunk routes.

8. COLUMBIA BROADCASTING SYSTEM, NEW YORK.

The emphasis here is mainly on television but unfortunately, as with N.B.C., there are no new studios in New York; in fact the opinion was expressed that to see modern techniques it would be necessary to visit Los Angeles. A new centre has recently been opened in Chicago.

As far as could be seen the techniques were generally similar to those in the B.B.C. The studios were treated on walls and ceiling with rockwool or fibreglass. In new studios, however, patches of treatment only are put on the walls, but no details were available on the reverberation time preferred. The impression was gained that, in fact, nobody cared very much. It was interesting that C.B.S. does not favour the separation of the sound mixer and, in fact, the whole team appears to be kept together as in our M.C.R.s.

Cardioid microphones are used almost exclusively on booms. The favourite microphone is the R.C.A. 77D, a ribbon microphone with variable polar characteristics. The Western Electric 639 A, which corresponds to the S.T. & C. 4033, and the Electrovoice 666 cardioid microphone were also observed in some places. An Electrovoice 666 has recently been tested by Research Department and found to be rather poor. A report is being prepared. In every case these microphones were fitted with windshields to reduce wind noise as they are swung on the boom. Great emphasis is placed on the need for personal microphones. Some very unsightly arrangements were observed in news broadcasts and talks where the people concerned carried round various types of microphone. There is therefore great interest now in the use of radio microphones which would to some extent get over this difficulty by avoiding trailing cable.

As regards sound insulation, no new techniques were discovered. In Television City in Los Angeles all the ancillary services such as dressing rooms and engineering facilities are included inside the main studio shell so that there can be no mutual interference between studios. In Chicago they are arranged outside so that there is risk of interference between one studio and the ancillary services of another unless great care is taken. In this respect the Television Centre resembles Chicago and not Television City.

While in New York a demonstration was witnessed of a new radio microphone manufactured by Portovox Corporation which seemed to be promising. It is doubtful whether it offers any technical advantages over the Designs Department microphone but if it is in quantity production the cost might be lower.

9. R.C.A., PRINCETON, NEW JERSEY.

The visit to R.C.A. Laboratories proved to be of great interest. After a general explanation of the activities of the laboratories, including a private demonstration of Electrofax printing, I was taken round the premises of the acoustics group. This group is engaged on the development of loudspeakers and microphones and the solution of other problems for N.B.C. and the R.C.A. organisation. One or two new loudspeakers have been developed, the most interesting being one which has already been described in the literature⁴. An early version of this loudspeaker was tested

many years ago by Research Department. It consists of two concentric cone loudspeakers using a common magnetic system. The smaller inner cone reproduces high frequencies and the large cone the low frequency end of the spectrum. To minimise the horn effect of the large cone on the high frequencies radiated from the small one, large conical projections have been mounted on the large cone and arranged spirally to give scattering of high frequencies. It was not possible to decide the performance of this loudspeaker from the demonstration given except to say that it is of a high order. If it were ever produced in Britain it might be of interest to the Corporation.

Work on microphones is also carried out by this group and a new ribbon cardioid microphone, type BK5A, is now available. Some time ago one of these microphones was ordered for test purposes but delivery is still awaited. As previously mentioned, a new second order pressure gradient microphone is being supplied to N.B.C. on a prototype basis. This microphone consists of a multiple ribbon assembly arranged to give a polar characteristic which is more directional than a cardioid. This microphone has, so far, no designation by which it can be ordered.

An experimental highly directional microphone was also seen, consisting of a section of a sphere about 4 ft in diameter, on which is mounted a large number of small loudspeaker units. These are damped acoustically to have uniform response and by connecting them together in the form of an array a very highly directional polar diagram is possible. The sensitivity is also great because of the aperture of the unit and the number of microphones. This device has not been tried out yet in the N.B.C. television service, for which it has been designed. In view of B.B.C. experience with highly directional microphones, it will be interesting to know whether the American producers will accept it. Some time ago a large reflector type microphone was constructed by Research Department and tested by the television service. It was rejected because its highly directional properties made it difficult to direct even with the sights provided. Its large size was also considered to be an embarrassment.

A specially designed miniature loudspeaker was demonstrated in a transistor receiver having dimensions about 4 in. x 3 in. x 1 in.

9.1. Sound Measurement Room.

The sound measurement room here is very large and is about the same size as the one at Harvard. The treatment consists of horsehair carpet felt blankets arranged in wedge shaped forms on all surfaces. It was surprising to see a heavy metal staging with handrails which was not removable from the room. It was claimed that this staging did not affect high frequencies; our experience however would indicate that this claim is not justified. In this room a machine with paddles was being used to produce wind for experiments with windshields on microphones. It was claimed that this was better than rotating the microphone on an arm because it produces more turbulence.

9.2. Sound Synthesiser.

Last year H.F. Olson described a device for synthesizing musical sounds⁵. Unfortunately the apparatus could not be demonstrated because the room in which it is installed was being painted. However, this equipment is of interest only for the

results it produces and it was possible to hear recordings. Analysis of musical sounds has shown that such an equipment to produce a realistic synthesis would have to be able to produce the required pitch, intensity, duration, the correct growth and decay, portamento (frequency glide), wave form and vibrato (low frequency modulation). The apparatus is set up separately for each musical instrument and the part is recorded on a punched paper record. This punched record is then used to control the synthesiser while a disk recording is made. The various parts of the composition are recorded on different bands on the same disk. These are assembled on a special reproducing and recording machine on which the disk with the various parts is carried on the same axis as the disk to be recorded so that complete synchronism is obtained. By these means it is possible to build up a complete performance with all the musical instruments simulated by the synthesiser. A number of short works has been performed in this way and the result is certainly impressive. There were obvious faults, but it was difficult to believe that the whole recording had been synthesised by one musician using no musical instruments at all. The device is, of course, also capable of producing unusual sounds but this aspect has not so far received so great attention.

9.3. Frequency Range Preference for Music.

It may be remembered that many years ago Chinn⁶, using $33\frac{1}{3}$ r.p.m. recordings for his experiments, claimed that listeners to orchestral music did not like high frequencies. Olson⁷, who is very keen on subjective experiments, decided to carry out a fundamental experiment. He placed an orchestra behind a curtain across the corner of a large room. Behind the curtain was a screen consisting of hinged sections which could be rotated as desired to attenuate high frequencies. He asked his subjects whether they preferred either of two conditions, one being with the attenuating screen and the other without. A marked preference was exhibited for the orchestra with its full high frequency range, thereby refuting the claims of Chinn. Apparently some of the comments by the listeners to the orchestra were rather embarrassingly frank because, not knowing that a live orchestra was behind the screen, some of them indulged in criticism of the performance. Some of the subjects also went so far as to complain of wow.

10. NATIONAL BUREAU OF STANDARDS, WASHINGTON.

Research Department has had much correspondence with members of the National Bureau of Standards, and recently the exchange of suitable reports has been arranged. It was therefore of great interest to visit the Bureau and discuss common problems.

It was not possible to see their sound measurement room techniques because they are at present re-building the old room. In common with all American rooms of this type it was noted that the wedges are being entirely enclosed in chicken netting. The formation of a cavity behind the wedges, or the alternative suggestion of Professor Meyer that the cavity at the back should be used as a Helmholtz resonator, have been considered and it is their opinion, with which we in fact agree, that nothing is achieved by the resonant cavity and that a space behind is quite sufficient. The wedges used are 3 ft 3 in. long and the density of the fibreglass 3 lb/cu ft, which is about the density of the wedges at Kingswood Warren. This room will be about the same size as the new one planned for Kingswood Warren.

Their reverberation room is also old. In it they make measurements of the properties of sound absorbing materials and, like the N.P.L., they use only one large sample. In other respects, however, their technique differs from the N.P.L. To produce a diffuse sound field they have loudspeakers mounted on large baffles which are rotated on a vertical axle at the centre of the room, whereas at the N.P.L. several loudspeakers are used at different positions in the room. The sample goes on the floor at the Bureau of Standards whilst it is mounted on one wall at the N.P.L.

There is at present considerable discussion going on internationally on the best way in which to measure sound absorption. The Germans favour the mounting of three samples on surfaces mutually at right-angles to simulate the practical conditions in rooms and this is the method which is employed by B.B.C. Research Department. This method however has the disadvantage that if the same total area of absorbent is used the samples are therefore smaller and the frequency at which the sample becomes comparable with the wavelength is consequently higher. When this happens edge effects due to diffraction take place which, as stated previously in this report, often give absorptions greater than unity. With one large sample this effect occurs only at much lower frequencies. On the other hand the placing of absorbers on one surface is not a practical condition in most rooms, and certainly not in studios. To try to elucidate some of the difficulties, the Bureau of Standards is now working on this problem of edge effects.

Facilities for measuring the sound insulation of partitions are available, but no work in this field was in progress.

One of the major projects in hand, but not applicable to broadcasting, is the standardisation of artificial ears and artificial mastoids for work on hearing aids.

11. KLEINHANS MUSIC HALL.

On the way from Washington to Toronto the opportunity was taken to visit the Kleinhans Music Hall at Buffalo, which was opened in 1940. It is one of the latest concert halls in America and is therefore much discussed. It is about the size of the Liverpool Philharmonic Hall but differs in that there are seats under the balcony. The accommodation is 3000, whereas in Liverpool, without seating under the balcony the accommodation is only 1770. In general the shape is similar, the hall being fan shaped. The ceiling is of plaster on expanded metal, but the plaster has been applied on both sides of the metal to damp resonances. In Liverpool Philharmonic Hall this was not done and there is a serious resonance at 110 c/s. The walls in the Kleinhans Music Hall are wood panelling with studding randomly distributed to minimise resonances. There are no seats behind the orchestra as is the case in most concert halls in this country, including Liverpool, and it therefore seems probable that there may be some trouble from the heavy instruments near the reflecting walls masking the quieter instruments in loud passages. No concert was heard in the hall so that an accurate assessment is not possible. Its characteristics are probably similar to those of Liverpool Philharmonic Hall, which means that the tonal quality may be a little harsh. The reverberation time is probably about 1.7 sec with audience present.

In addition to the large music hall there is also a small hall, horseshoe shaped, of a similar construction to the large one. The floor here, however, is

flat, as the hall is intended for general purposes. It seats 800 and will probably have a reverberation time of about 1 sec with audience present. It is reputed to be very good for speech or small orchestral combinations.

12. CANADIAN BROADCASTING CORPORATION.

12.1. Toronto.

This visit was paid on the Saturday of the Dominion Day weekend and so only junior members of C.B.C. were seen. Visits were paid to both television and sound studios of C.B.C.

It was noted that in the sound studios there was no provision for diffusion, except in one or two cases. All the porous absorption is placed behind Johns Manville perforated tiles, no fabric being used in any studio. Consequently, in all the studios the high frequency response is excessive by our standards and the sibilance is very marked. As far as could be ascertained, this did not prove to be a disadvantage, the reason probably being that the loudspeakers used for monitoring have a poor high frequency response which prevents the sibilance being heard by the C.B.C. staff. In addition to this, the fact that the telephone lines cut off at 5000 c/s probably protects the listeners from the results of sibilance in the studios. Low frequency absorption is obtained by various forms of panelling. In no case was there any attempt to use high efficiency absorbers such as the membrane type used in the B.B.C. Most of the orchestral studios are too small for the orchestras which normally use them and this means that it is not possible to employ single microphone techniques, although it is agreed that this is desirable. For the sound service an old cinema has now been taken over as a large orchestral studio.

The most favoured microphones are the R.C.A. 77D, used as a cardioid and the R.C.A. ribbon 44BX, a pressure gradient microphone; some Western Electric 639A cardioid microphones were also in use.

Several new studios have been provided for the television service. The acoustic treatment consists of areas of 1 in. rockwool or fibreglass on the walls and ceiling. This is placed on the walls without a cavity and therefore there is little bass absorption. There is no doubt that the acoustics of these television studios would cause complaint in the B.B.C. from the drama and variety departments because of long reverberation time particularly at low frequencies. Microphones are used on booms, the favourite being the R.C.A. 77D.

The sound mixer is segregated from the rest of the team, as is done in B.B.C. and N.B.C. but not in C.B.S. In one audience studio the sound reinforcement system consisted of a multiple loudspeaker arrangement over the audience, operating at low level, because it is apparently customary for the artists to walk among the audience. The only way in which sound reinforcement can then be accomplished is to have an operator adjusting the levels to the various loudspeakers. This complicated system did not seem worth while from the results achieved. As far as the sound side of television is concerned, apart from the differences mentioned, methods appear to be approximately similar to those used in the B.B.C.

12.2. Ottawa.

On the way to Montreal from Toronto a brief visit was paid to Ottawa. New studio premises have been built at the site of the television transmitters and here the techniques were exactly similar to those found in Toronto. Once again the studios were rather lacking in treatment, but this seems to have caused no difficulty so far.

12.3. Montreal.

The main engineering effort of C.B.C. is concentrated in Montreal. Here again, because of the holiday only junior staff were available. A new building was completed some years ago for the sound service but one or two television studios are also incorporated in it. It is situated on one of the main avenues of the city and to give isolation from traffic noises all the studios on the ground floor are floated on steel springs. These precautions appear to be very satisfactory for the isolation of street noise.

The treatments used in the sound studios are basically similar to those seen in Toronto but more modern. Diffusion has been introduced in these studios in which the porous absorbers are all covered with hard perforated panelling. The result is once again excessive sibilance, but here, as in other parts of Canada, this does not appear to cause any concern in the programme departments. Apparently when the studios were new the sibilance was noticed but nothing was done to cure it and it has now been accepted. For the reasons previously mentioned, it does not appear to trouble the listeners. Another alleviating factor is that V.H.F. broadcasting is not popular in North America and therefore wide frequency range has no significance. It is probable that if frequency modulation had become widely established the Canadians might have found themselves in the position of the Germans who have had to take steps to reduce the sibilance in their studios and remove sources of distortion at high frequencies.

During discussion with some of the junior technical members of C.B.C. it was found that the only high grade monitoring loudspeakers in use, and this is only in certain key positions, were some old Cinaudograph loudspeakers. Most of the day-to-day monitoring is carried out with Wharfedale Golden units in cabinets made up locally.

In America it was noted that for talks and discussion programmes various types of microphone were quite openly carried by the speakers. This is not the case in Canada where the production technique resembles closely that of the B.B.C. Although extensive study was not possible in the short time available, it appeared that the sound on Canadian television was superior to that of American television.

In addition to the new premises built some years ago, C.B.C. is also using external halls for the larger television productions. A new building programme is in progress to extend the main studio centre, and to provide more studios for television.

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